SEGMENTATION AND CLASSIFICATION OF BURN COLOR IMAGES

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***Abstract*-The aim of the algorithm described in this paper is to separate burned skin from normal skin in burn color images and to classify them according to the depth of the burn. The segmentation procedure consists of an elaborated treatment of color representation, followed by a grayscale segmentation algorithm based on the stack mathematical approach. The proposed algorithm has been developed to be applied to skin wound images, but it works properly as a general segmentation approach. In the classification part, we take advantage of color information by clustering, with a vector quantization algorithm, the color centroids of small squares, taken from the burnt segmented part of the image, in the (V_1, V_2) plane into two possible groups, where V1 and V2 are the two chrominance components of the CIE Lab representation.**
Keywords: **Multiresolution segmentation, color image processing, vector quantization.**

I. INTRODUCTION

In this paper a burn color image segmentation and classification algorithm is proposed.

The motivation of this work stems in the fact that it is required as part of an automatic system to give a first assessment about the depth of a burn wound. For a succeeded evolution of a burn injury it is very important to state the first treatment [1]. To choose an adequate one, it is necessary to know the depth of the burn. As the cost of maintaining a Burn Unit is very high, it would be desirable to have an automatic system to give a first assessment in all the local medical centers, where there is a lack of specialists [2,3].

The image processing has several advantages when it is applied to give the assessment of skin lesions and ulcers: the image processing techniques are objectives and reproducible. The color image processing has an important future as the analysis and comparison of color images are not an easy task, and it is acquire by experience. With the fast advances in technology, the Computer Aided Diagnosis (CAD) systems are getting more popular. However, nowadays, the research in the field of color skin images is limited to two main applications [4]. They are the assessment of the healing of skin wounds or ulcers [5-7], and the diagnosis of pigmented skin lesions such as melanomas [8-10]. Nevertheless, this research is being developed slowly due to the difficulty of translating color human perception into objective rules, analyzable by a computer. That is why automation of burn wound diagnosis is still an unexplored field. However, in the related literature, there is a research tendency to search objective methods to determine burn depth. This research effort arises to mitigate subjectivity and high experience requirement in visual inspection. In this way, research about the relationship between depth and superficial temperature [11], sometimes employing thermographic images [12], has been done. Other works have tried to evaluate burn depth by using infrared and ultraviolet images, radioactive isotopes, Doppler laser flux measurements [13-15]. These techniques have limitation not only in diagnosis accuracy but also in unallowable economical cost.

In spite of that, there is hardly bibliography about burn depth determination by visual image analysis and processing [16,17]. On the contrary, there is a wide medical bibliography about burn wound diagnosis by means of visual inspection.

In the work described in this paper, we develop a method to segment burn wounds in digital photographs and to classify them afterwards. In Section II we describe burn wound classifications. We devote Section III to describe the segmentation part. In Section IV, the classification method is presented. Finally, results are shown in Section V.

II. BURN CHARACTERIZATION

There are three main types of burn depth (superficial dermal, deep dermal and full-thickness), but in this paper we are focusing on the first two groups, because they mark the border of the requirement of grafts.

1) *Superficial dermal burn*.- It is characterized by the presence of blisters (usually brown color) and/or a bright red color. So, we have assigned a region in the (V_1, V_2) plane to each appearance.
2) *Deep dermal burn*.- It is characterized by its red-whitish color, with dark dots.

III. SEGMENTATION PART

The proposed segmentation approach is a multiresolution method, because of the need to attempt to gain a global view of an image by examining it at many different resolution levels. This proposed method is based on a grayscale multiresolution segmentation algorithm,

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described by Lifshitz and Pizer [18] founded on the mathematical stack approach [19]. The stack calculates image segments and an image description tree by associating every pixel in an image with a local intensity extremum. The initial color version of this algorithm is described in [20]. In this work we present a transformation to segment accurately any type of burn wound.

A. The Stack Approach

In the stack approach the image is described in terms of *extremal regions*. This description is produced by identifying the extrema in a stack of images in which each higher image is a slightly blurred version of the previous one. Progressively blurring an image causes each extremum to move continuously and eventually to annihilate as it blurs into its background. Following the locations of an extremum across the stack of images forms an *extremum path*.

Intensity change must be monotonic (increasing for dark spots and decreasing for light spots) as one moves along an extremum path from the original image towards images of increased blurring. As a consequence, an extremum region can be defined, in the original image, as formed by those pixels around the extremum point that fit the following condition:

- Their intensity is higher or equal to the annihilation intensity for that extremum, if it is a maximum.
- Their intensity is lower or equal to the annihilation intensity for that extremum, if it is a minimum.

An extremum annihilates when the blurring is sufficient to make the light or dark spot blur into an enclosing region. The amount of blurring necessary for an extremum to annihilate is a measure of the importance or scale of the extremal region. The intensity of the topmost point on an extremum path is the path's *annihilation intensity*. This is the intensity of the isointensity contour that forms the boundary of the associated extremal region.

A Gaussian kernel is used as blurring function [18].

B. Discrete Image Segmentation

Theoretically, this procedure could be applied as it for continuous images, where to reach a particular intensity from another one there is always a path with every value between them. Therefore, rounding every extremum there will be always any isointensity contour with intensity between its initial intensity value and its annihilation intensity. But this does not happen in digital images. Nevertheless this limitation can be easily overcome by looking for a contour, surrounding the extremal point, that contains those pixels with the intensity nearer the annihilation one and above it. Additionally, under certain circumstances –mainly when there is not a big difference between the interest object and the background–, a maximum annihilates after too many blurring steps and the annihilation intensity results too high –for a minimum, too low in the case of a maximum–. Consequently the annihilation intensity does not define adequately object boundaries. And so, instead of choosing the annihilation value, we choose the extremum intensity resulting after a defined number of blurring steps. This number is proportional to the extremum value and its changing speed.

Finally, due to discreteness of pixel values, at the first step, in the original image, too many extremum values appear. Significant extrema are selected by refusing those with intensity outside a tolerance band around the highest maximum and the lowest minimum. Furthermore, only those extrema that annihilate after a defined number of steps are considered.

C. Color Segmentation Applied to Burn Wound Images

To segment color images we first perform a color transformation to HSI coordinates, where distances are more correlated with color change human perception. The following step is to summarize the three coordinate color information for every pixel into an only magnitude. To avoid dependence on lighting conditions, the luminance coordinate is not considered. So, the intensity magnitude characterizing each pixel is form with the saturation coordinate weighed up by a function depending on the color, represented by the hue. The weighing function is:

$$w(h, hc, \alpha) = \cos^3\left(\frac{h - hc}{\alpha}\right), \qquad (1)$$

where *hc* is the angle of the color we want to emphasize. α is a parameter that chose the range of colors to be segment. We choose this particular weighing function to emphasize the directivity of the cosine function, which results too smooth to be applied as weighing function in our segmentation application.

Finally, the complete intensity value assigned to every pixel for segmentation is:

$$i(x, y) = s \cdot w(h, h_c, \alpha)\,(x, y)\,, \qquad (2)$$

where *s* is the saturation component.

IV. CLASSIFICATION PART

A. Color Feature Extraction

It has been proved that physicians determine the depth of a burn based on color perception, as well as on some texture aspects. This implies that if a color metric in accordance with human perception is applied, we will get a color feature adequate to attain our goal of classifying burn wounds. The color representation based on human color matching is the CIE *Lab* color space, since it was designed so that intercolor distances computed using the $\|\cdot\|_2$ norm correspond to subjective color matching data [21]. *Lab* color system represents a color by three coordinates: the luminance, I, and the two chrominances, V_1 and V_2. These last two components will be the ones we will employ to describe the color of a particular image

After segmenting a burn wound in an image, this wound is divided into 9×9 squares. For each square the average of the chrominance coordinates (V_1, V_2) is calculated. These two values are given to the classifier.

B. Classification Procedure.

As it was mentioned above, in the *Lab* color system, $\|\cdot\|_2$ norm corresponds to perceptual similarity, thus representing the optimal distance metric for that space. That means that this will be a good measure to classify colors into the three groups, each corresponding to one aspect (two of them are of the same group) of burn wound. And to obtain the optimal centers and decision boundaries of the regions corresponding to each group we apply the LBG vector quantization algorithm [22] as it minimizes the overall mean-square classification. The quantizer is trained with 96 images 49×49 of burns of the different depths. After the training, the centroids are fixed, and the quantizer is used for classification. The inputs for the classification are 9×9 squares, taken from the segmented part of the image, that is supposed to be the burned part.

V. Experimental results

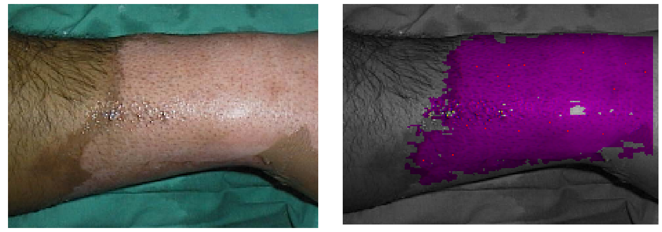
We apply the segmentation and classification algorithms on nine burn images. Those images are digital photographs taken by physicians following a specific protocol [3]. All the images were diagnosed by a group of plastic surgeons, affiliated to the Burn Unit of the Virgen del Rocío Hospital, from Seville. The assessments were validated one week later, as it is the common practice when handling with burned patients.

Three of the images correspond to superficial dermal depth, three to deep dermal depth, and the last three have both types of burns.

A. Segmentation Results

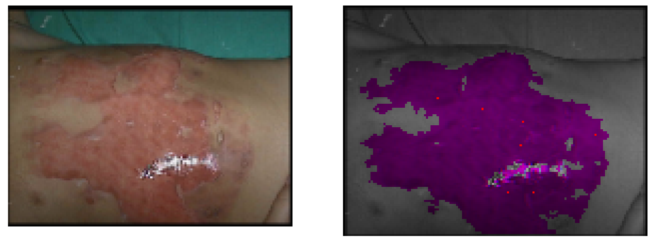
To perform the segmentation, a previous characterization of the hue and saturation component histograms for both normal and burnt skin was needed. This was done in order to fix the parameters h_c and α in equations (1) and (2).

In all the cases, the burn wound was segmented correctly from the normal skin. Fig. 1 to 3 show the segmentation results for one image from each of the three types defined above. Fig. *a* represent original images and Fig. *b* represent the segmented ones. In the segmented images we have marked with violet color the segmented region on greyscale photographs.



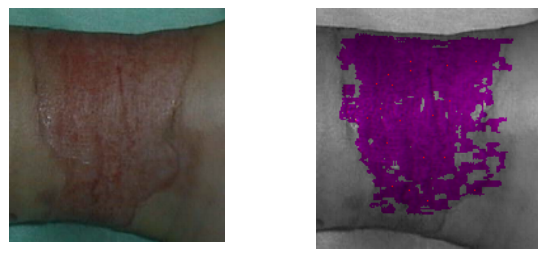
(a) (b)

Fig. 1. (a) Original superficial and deep dermal burn image, (b) segmented image.



(a) (b)

Fig. 2. (a) Original superficial dermal burn image, (b) segmented image.



(a) (b)

Fig. 3. (a) Original deep dermal burn image, (b) segmented image.

B. Classification Results

As mentioned before, the segmented parts of the images were divided into 9×9 squares. The (V1,V2) centroids of these square are calculated and given as inputs to the classifier. A majority criterion is followed to assigned a type to the photograph. In Table I the classification results are presented. In this table, the percentage of squares in the suitable class among the total number of squares in the wound appears in the last column. Mixed burn wounds usually have small surface of deep dermal burn. That is why a small percentage of squares are considered as a deep dermal wound. In these types of images it is represented the percentage of squares classified as superficial dermal / deep dermal. Nevertheless, photographs 7 and 9 should be considered as misclassified.

TABLE I.
Classification results for the nine photographs analyzed

Photograph	Type	Percentage of squares classified as it
number 1	superficial dermal	99.20 %
number 2	superficial dermal	100.00%
number 3	superficial dermal	100.00%
number 4	deep dermal	98.22%
number 5	deep dermal	85.30%
number 6	deep dermal	78.91%
number 7	both	99.85% / 0.15%
number 8	both	91.06% / 8.94%
number 9	both	99.52% / 0.48%

VI. CONCLUSIONS AND FURTHER WORK

In the present paper a color image segmentation and classification method is proposed for burn color images. It has been shown its good performance when segmenting and classifying the images into superficial and deep dermal types. We are working now in enlarging the database, as well as extending the algorithm to full thickness burns. For this purpose, we are taking into account the texture of the burns and not only the color information.

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